

Micro-Aerial Vehicles Materials & Structures

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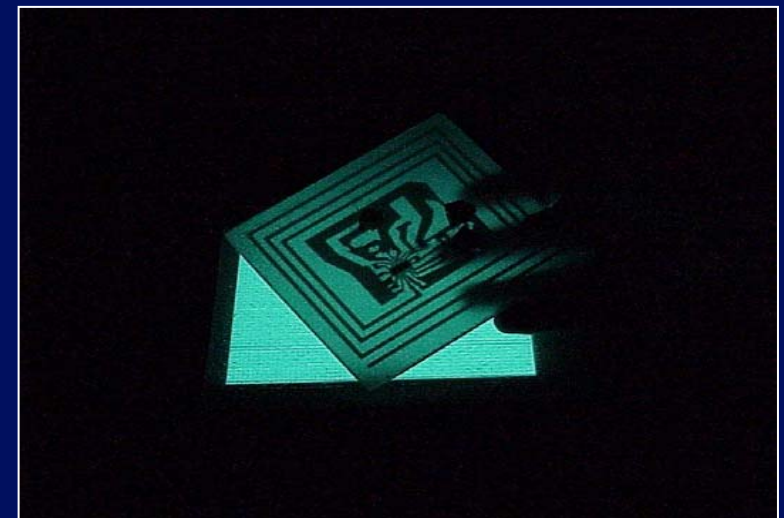
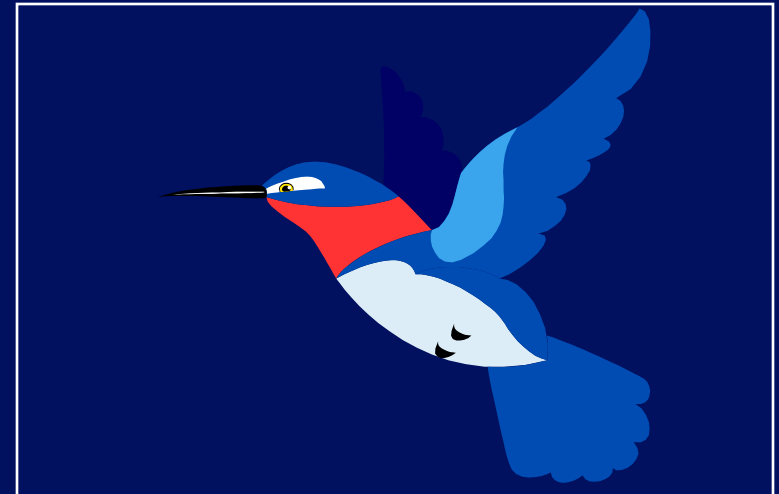
Where are we now ?

- Simple platforms
- Mini rather than Micro
- Hobby shop materials
 - balsa wood; polystyrene foams; sticky tape
- Aero-modelling technology
- Lack of integration



Where do we need to be ?

- Lighter weight
- Damage tolerant
- Reduced size
- Engineered joints
- Integrated design
- Multi-functional
- Designed for purpose



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How do we get there ?



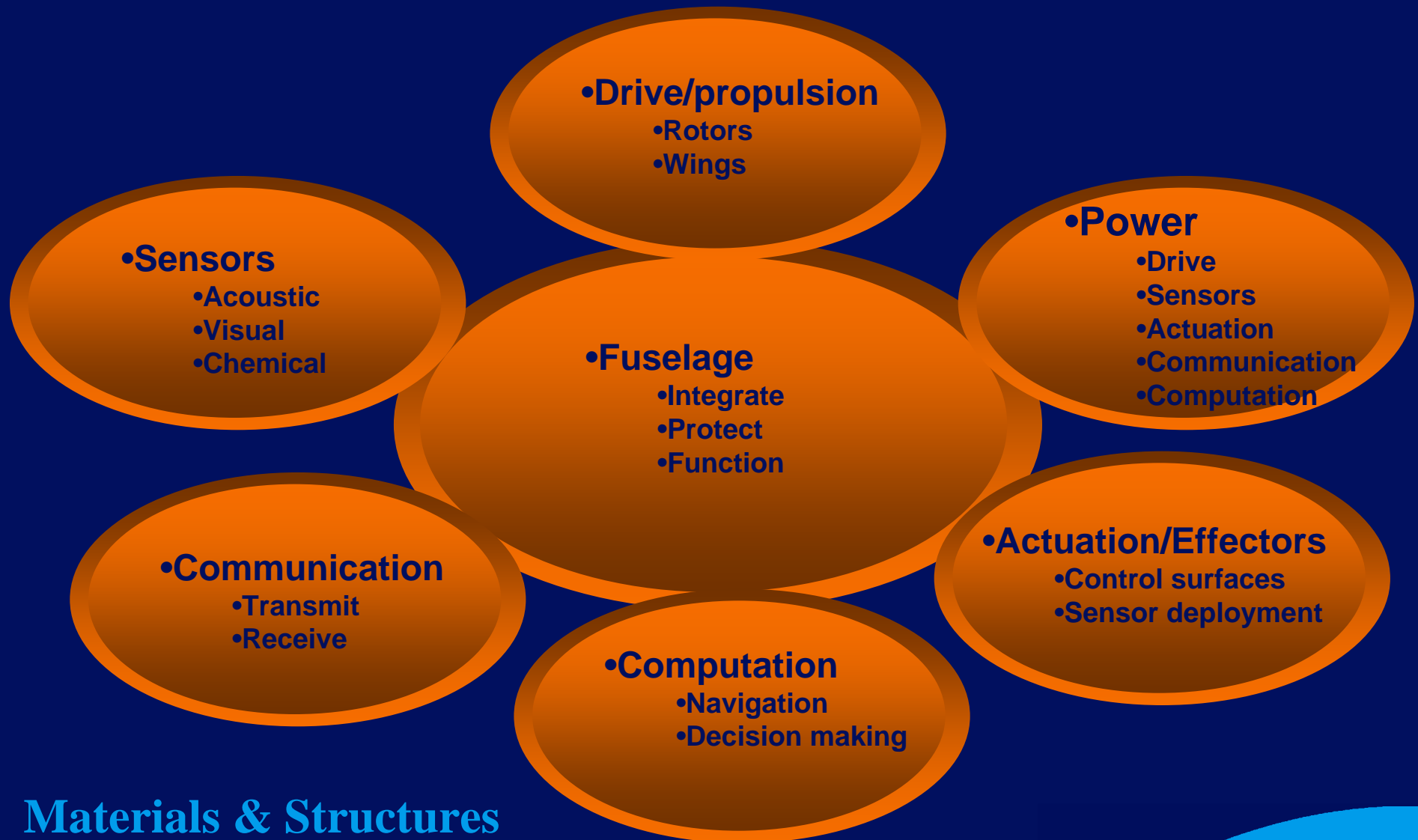
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Integrated system of systems



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The Technical Drivers [1]

To design, manufacture and deploy miniature airborne military platforms of typical size 20 - 150mm : [components ~0.1 to 10mm].

- **Mass and volume efficient materials - specific strength, stiffness.....**
- **Structural forms - foams, spaceframes, anisotropy.....**
- **Robustness - shock resistance, self-healing.....**
- **Structural integration - stress/heat transfer, cross-talk.....**
- **Actuators - force, strain, bandwidth, power.....**
- **Biologically-inspired materials & mechanisms - nano, folding.....**

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The Technical Drivers [2]

- **Material and structures characterisation - scaling, micro-testing...**
- **Multifunctional materials - integrated actuation, antennae, power....**
- **Low observable treatments - acoustic, vis/IR, radar.....**
- **Machining and shaping - moulding, milling, MEMS.....**
- **Joining techniques - adhesives, snap-fit, electrical...**
- **Assembly / deployment / recovery - quick fit / release**
- **Affordability - materials, manufacture, re-use, commercial infrastructure....**

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Military need

- **Military need \Rightarrow Mission \Rightarrow Device performance \Rightarrow Device design \Rightarrow Structures \Rightarrow Materials**
 - payload mass, range, speed, environment,
 - one-shot/re-use, loiter time.....
- **Leads to description of vehicles properties**
- **Leads to materials and structure requirements**
- **Mission scenarios needed to allow detailed directed materials and structures research and development**
- **Useful underpinning activities \Rightarrow 'toolkit'**



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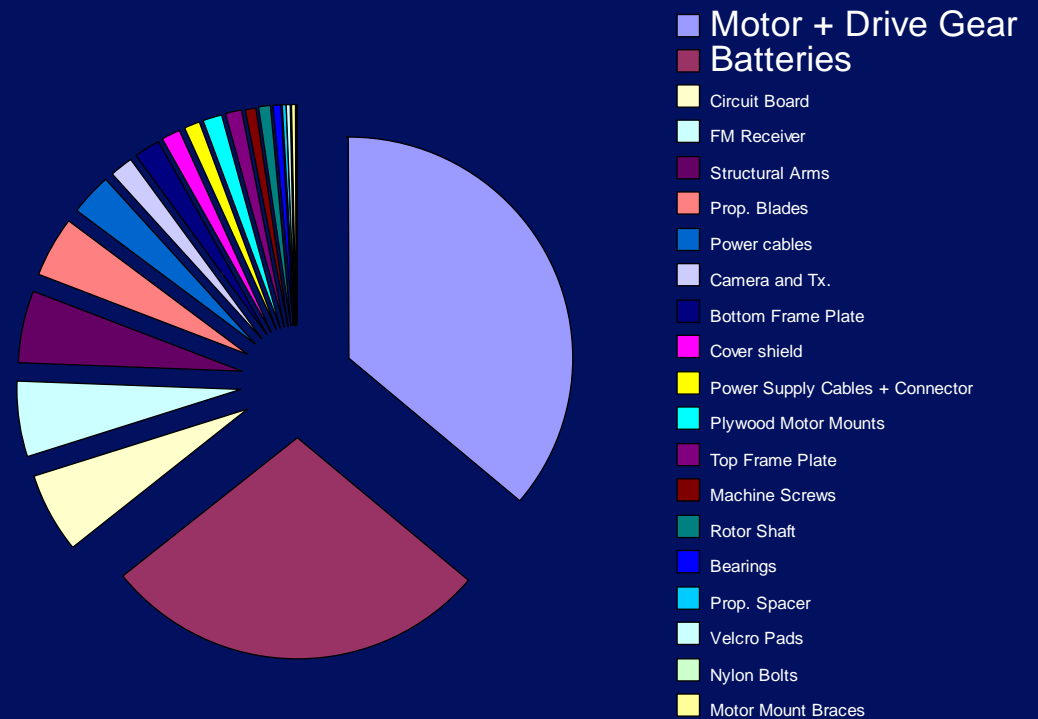
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Mass and volume efficient materials

- **Specific strength**
 - **Specific stiffness**
 - **Elasticity**
 - **Specific conductivity**
 - **Specific power density**
 - **Thermal conductivity**
-
- **For all electric MAVs - primary power chain**



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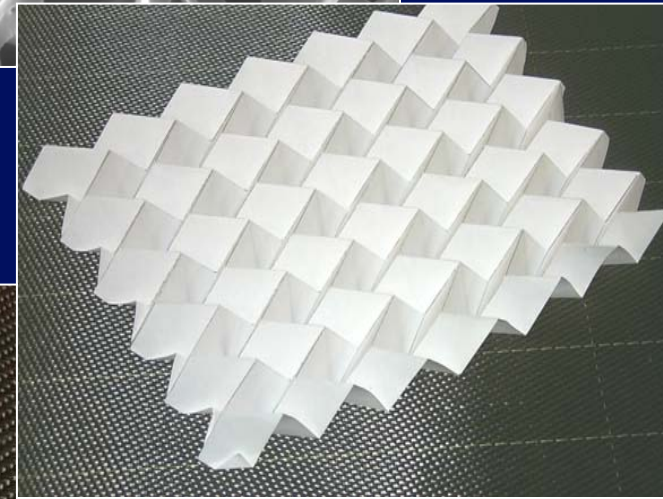
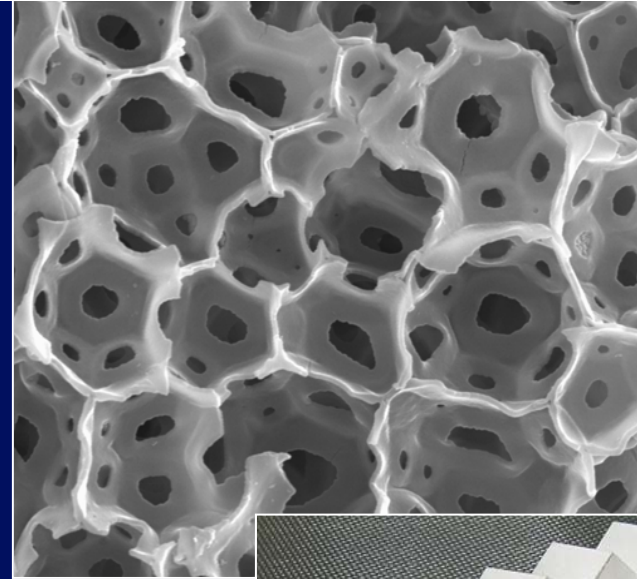
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Structural forms

- Foam core sandwich materials
- Novel core sandwich materials
- Space frames
- Curvilinear forms
- Anisotropy
- Micro-foamed polymer materials
 - reinforced (fibres, nano-platelets)
- Micro-foamed metals
 - syntactic, blown



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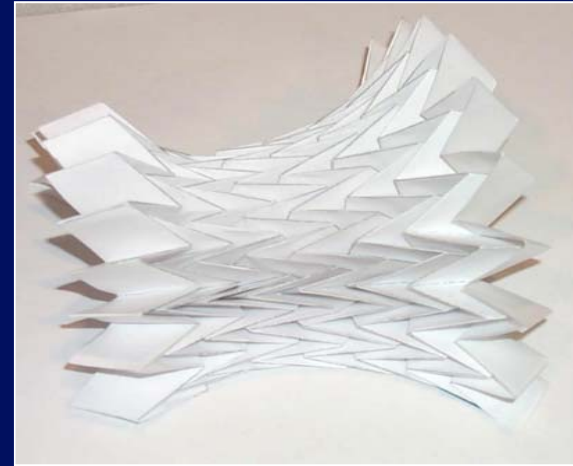
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Biological-inspiration

- **Nano-composites**
- **Folding extensible structures**
- **Aeroelastic structures**
 - **anisotropic structures**
- **Curvilinear, foam core and space-frame**
- **Smooth ‘simple’ resilient outer surfaces**
- **Protection of vital systems**
- **Don't attempt to copy nature, be inspired**



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Machining and forming processes

- **Moulding - model kits - cheap, poor tolerances ?**
- **Milling & 'micro engineering' - the watch industry**
- **MEMS - 2D / Quasi 3D**

Joining

- **Sub-component designs - integrated assemblies**
- **Fixing, snap-together - manufacture & operational assembly**
- **Adhesives - droplet size / wetting**
- **Weld / solder - heat affected zone**
- **Electrical - power & data**

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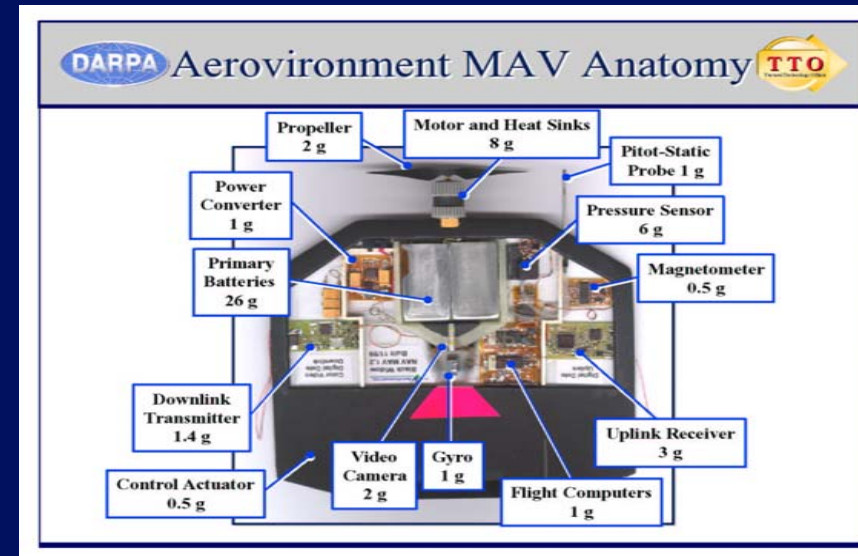
Structural integration

- Stress transfer
 - large surface to volume ratio
 - bond edges / heat affected zones
- Heat transfer
 - high power / compact device
- Layout restrictions
 - sensors / effectors
- Adverse interactions
 - cross-talk (proximity)
- Affordable manufacturing

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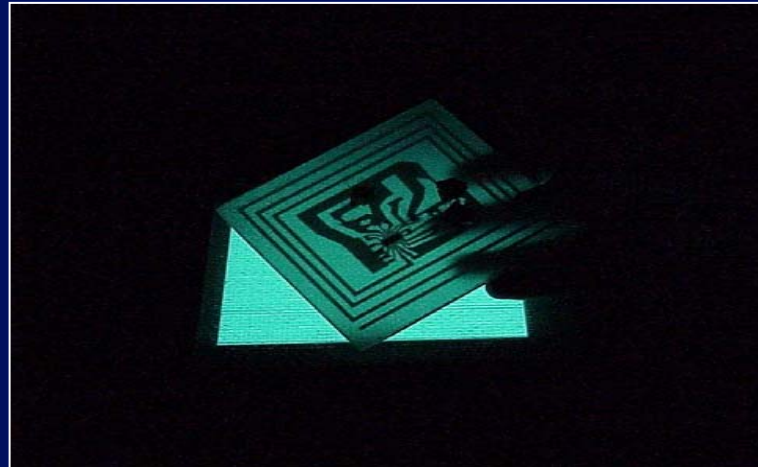
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Multifunctional structures

- Integrated actuation - lubrication / gaps (dirt ingress)
- Antennae
- Energy storage
- Low observability



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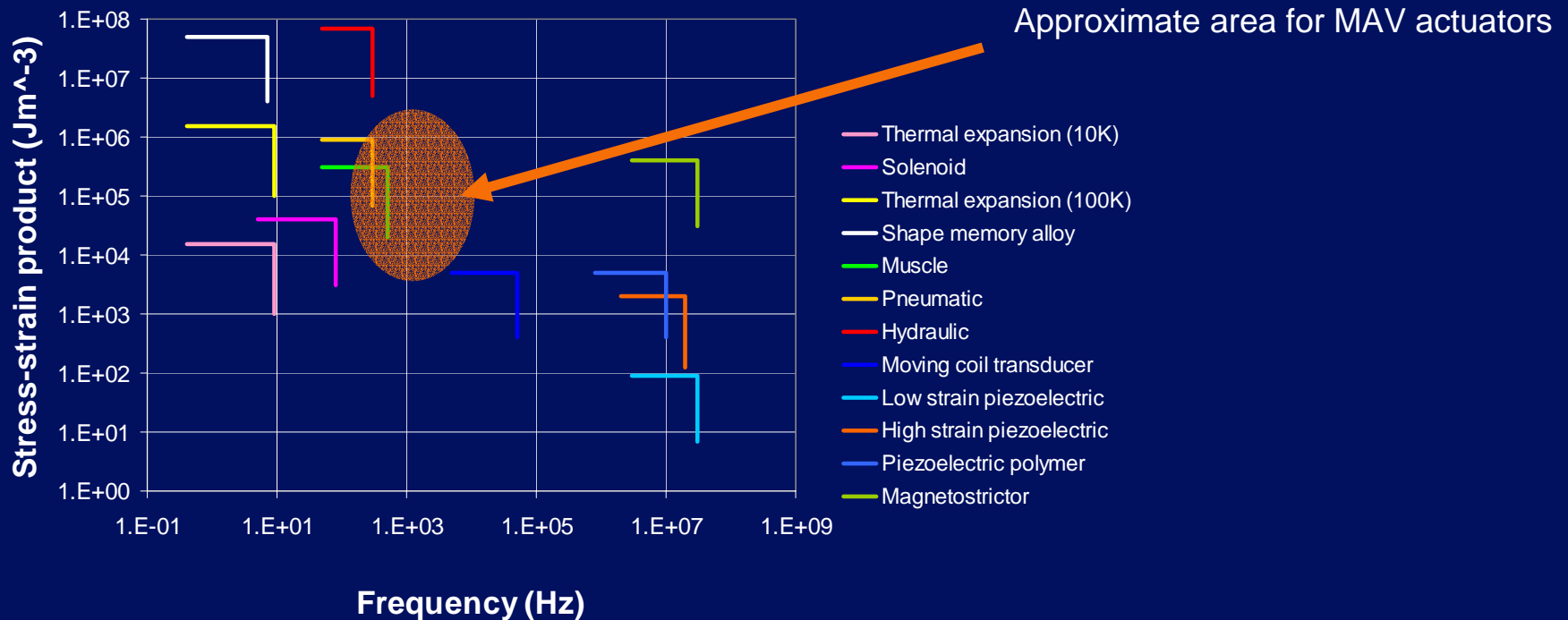
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Actuators

- High **specific** force & strain, bandwidth.....
- Rotary, linear or reciprocating
- Power requirements



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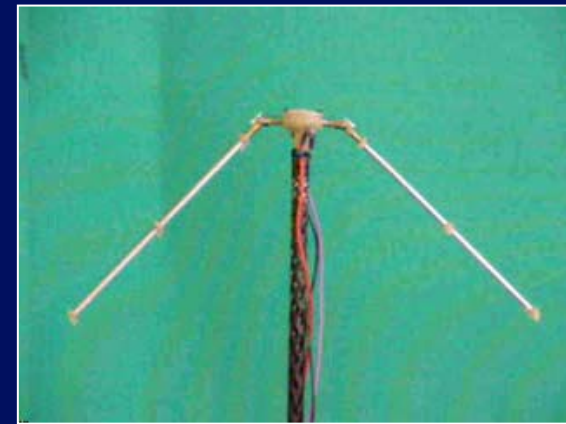
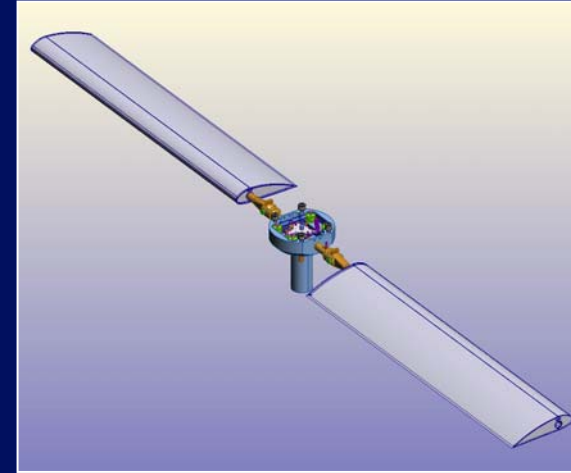
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Deployment systems

- **Assembly / shape change for launch**
 - automatic vs. hand assembly
 - latching actuation
- **VTOL /cassette / hand / rolling launch**
 - low shock launch to flight speed
 - pneumatic, 'bungee'
- **Munitions launch**
 - high shock launch, flight to operational area
 - rocket, mortar, shell.....
- **Landing - rolling / net /crash....**



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Robustness

- Storage, transport, launch, collision, landing...
- Shock / impact resistance, self-healing, quick-release, spares kit.....
- Environmental robustness
[all weather operations....]



Affordability

- **Materials**
- **Manufacturing**
- **Commercial infrastructure**
- **Production volume**
- **Dual-use**
- **Re-usability**
- **Repair**



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Some thoughts to remember

- **Primary power train remains heaviest subsystem**
 - how can we make this **SIGNIFICANTLY** lighter
- **Nature has evolved competent MAVs**
 - inspirational, but different 'mission'
- **Plethora of materials and structures that could be used**
 - be selective, simple designs, simple lines if you can
- **Think 'multifunctionality'**
- **Small component engineering**
 - need true 3D machining at 0.1 to 10mm range
- **MAVS will crash, collide and be handled by people in a hurry**
 - robust materials and designs - think of MAVs for 3yr olds !

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